The Multipole Structure of the Local Expansion Rate

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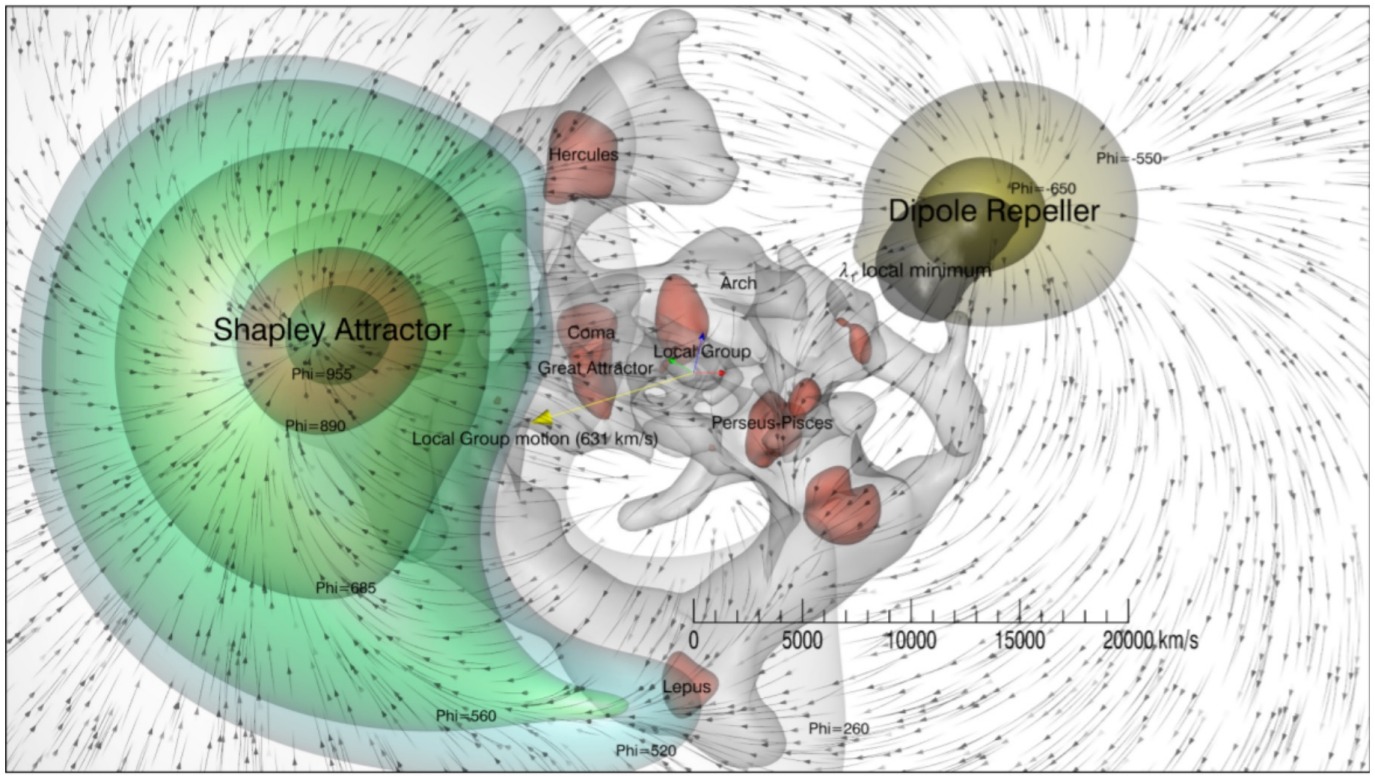
Tensions in Cosmology Corfu 08/09/2022

On local scales the Cosmological Principle is violated

Our interest is in the local structure of spacetime.

Not interested in peculiar motions but in unperturbative approach: fluctuations in the scale factor(s)

Looking for an observable that is easily comparable with theoretical predictions



Hoffman et al 2017

The expansion rate fluctuation

$$\eta_d = log\frac{\widetilde{H}}{H_0}$$

$$\widetilde{H} = \frac{z}{d}$$

The estimator is a r.v. with Gaussian distribution

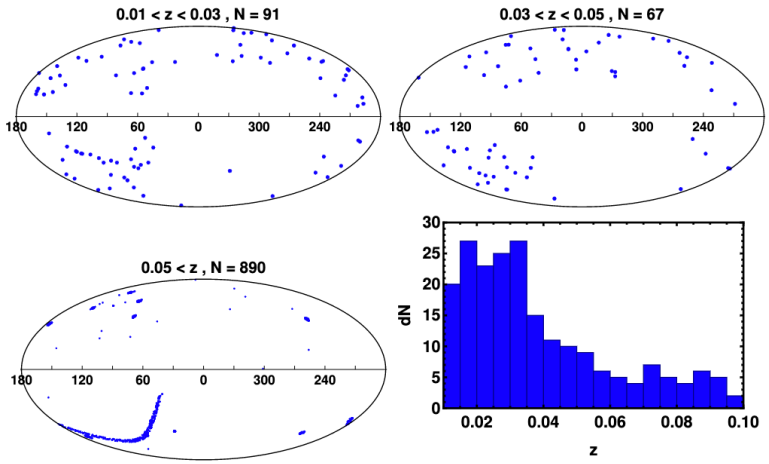
The estimator is statistically unbiased

The condition $\langle\eta\rangle$=0 ensures independence from the monopole (H_0)

Simple physical interpretation within the FRW cosmological model
(if radial peculiar velocity v<<z)

$$\eta_d \approx \frac{v}{\mathrm{z\ ln\ 10}}$$

Data



Pantheon sample (Scolnic et al. 2018)

z-independent distances using SNIa as standard candles

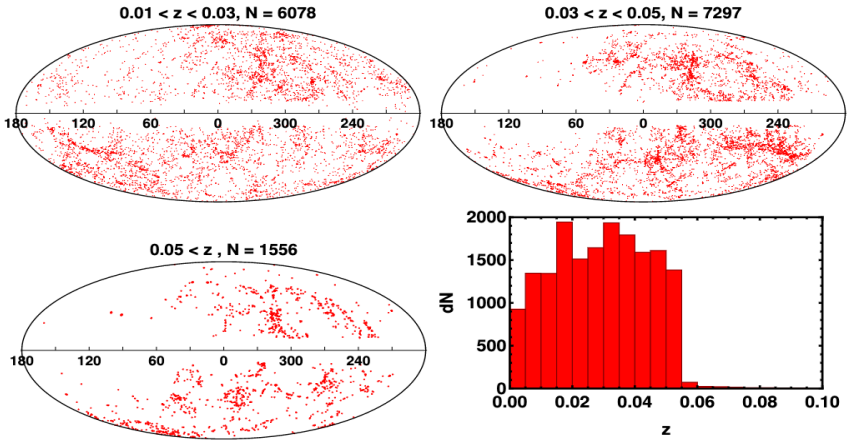
~160 objects with z<0.05

Cosmic-Flows 3 (CF3) (Tully et al. 2017)

z-independent distances using TF & fundamental plane

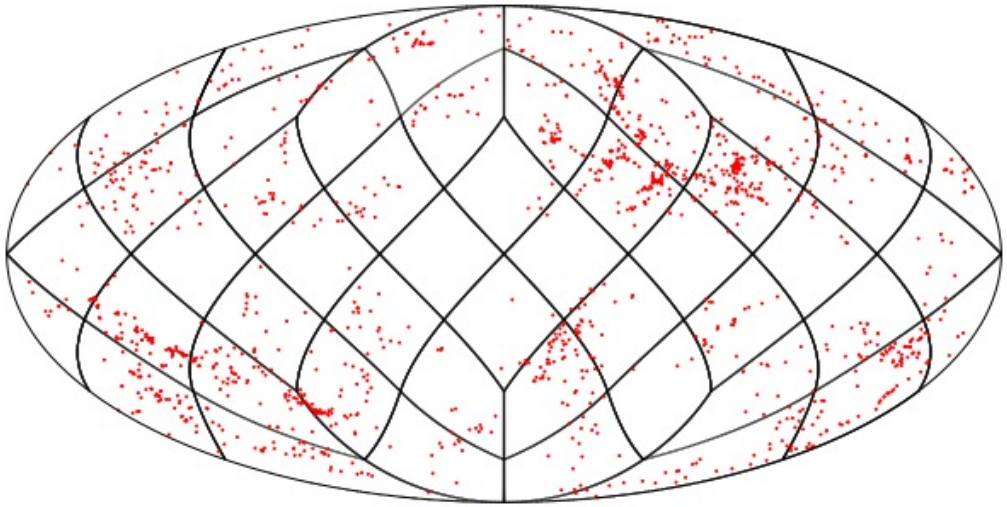
Larger errors (reduced by group assignment strategy)

~13660 objects with z<0.05 (including ~290 SNIa)



The expansion rate fluctuation reconstruction

HEALPix tessellation



The expansion rate fluctuation reconstruction

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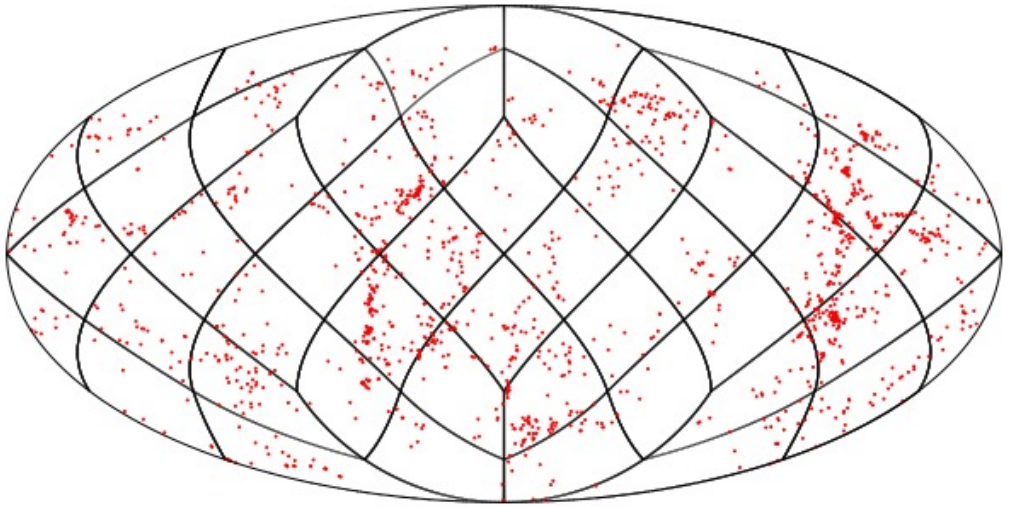
Rotation to handle angular incompleteness



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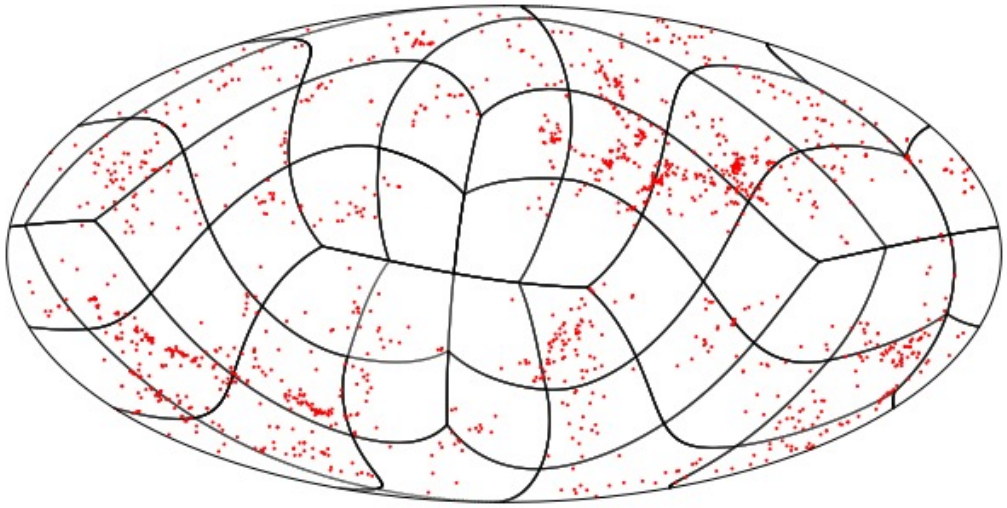

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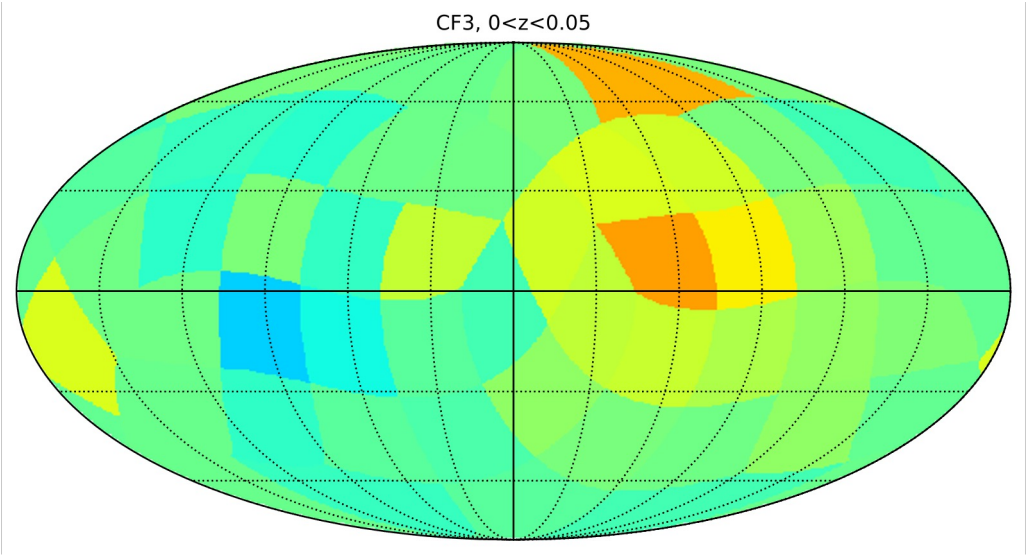
Rotation to handle angular incompleteness

Signal is then decomposed on the SH basis

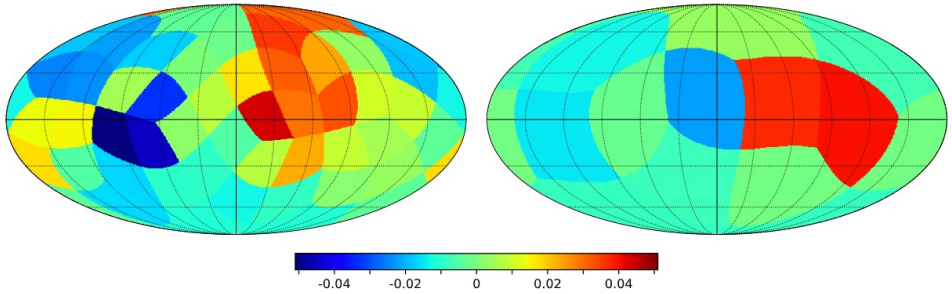
$$\eta = \sum_{lm} a_{lm} Y_{lm}(\theta, \phi)$$



Relevant SH quantities (power spectrum coefficients, angular coordinates of principal axes of the multipoles etc…) are all corrected by means of Monte Carlo simulations to minimize systematic induced by anisotropic sampling and data sparsity.

CF3 galaxies (48pix)

CF3 SNIa (12 pix)



Multipoles of the expansion rate fluctuation

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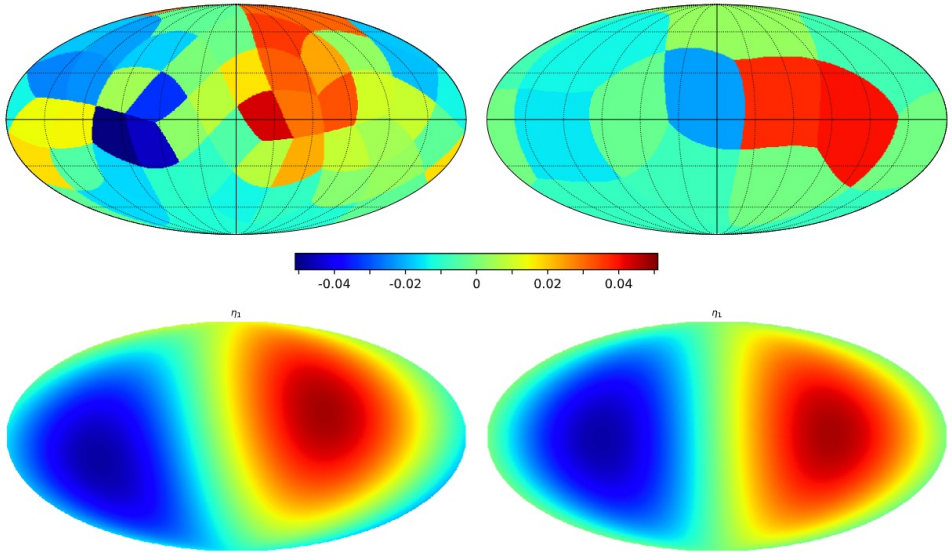


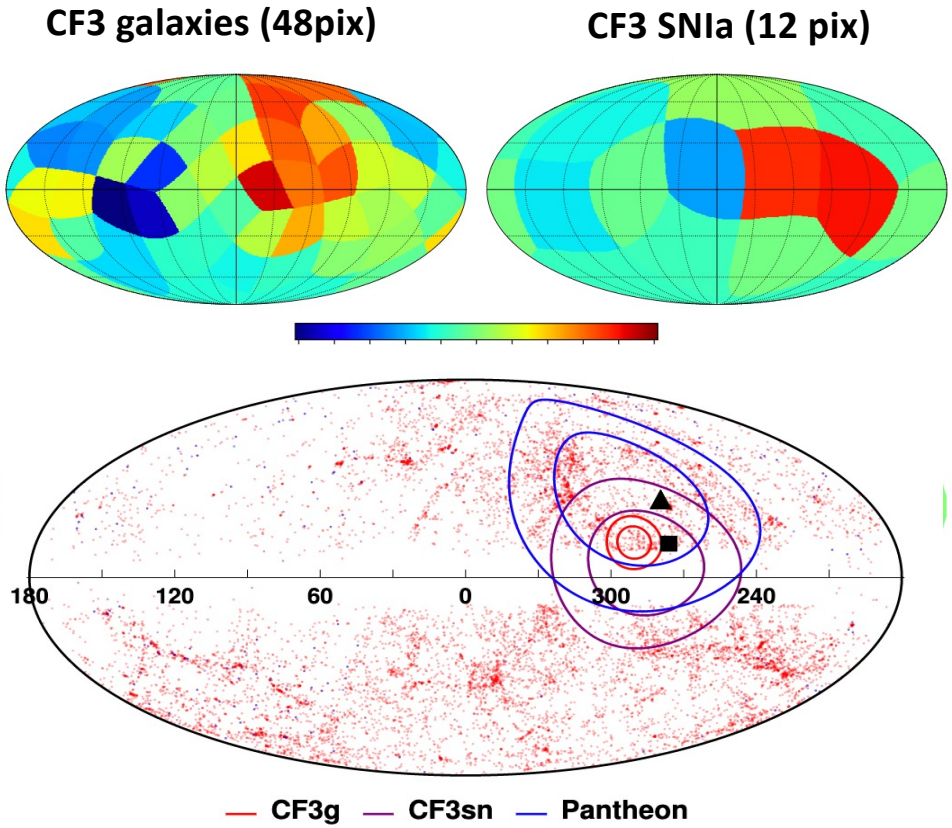
Multipoles of the expansion rate fluctuation

Same intensity and direction (CF3g, CF3sn and Pantheon)

Signal 2% of monopole → Bulk $(312\frac{km}{s}, l{\sim}286^{\circ}, b{\sim}4^{\circ})$

(Nusser & Davis 2011, Turnbull et al 2012, Scrimgeour et al. 2015, Boruah et al. 2021)

Same direction as bulk component of LG motion ($l{\sim}276^{\circ}, b{\sim}12^{\circ}$)



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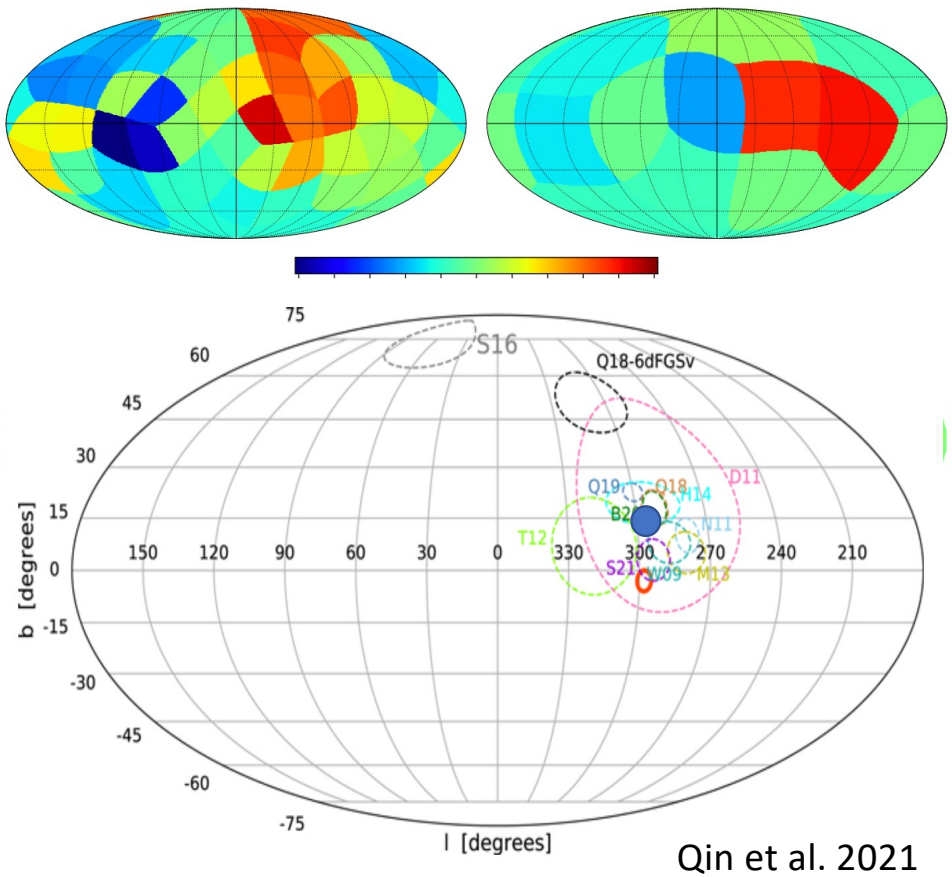

Qin et al. 2021

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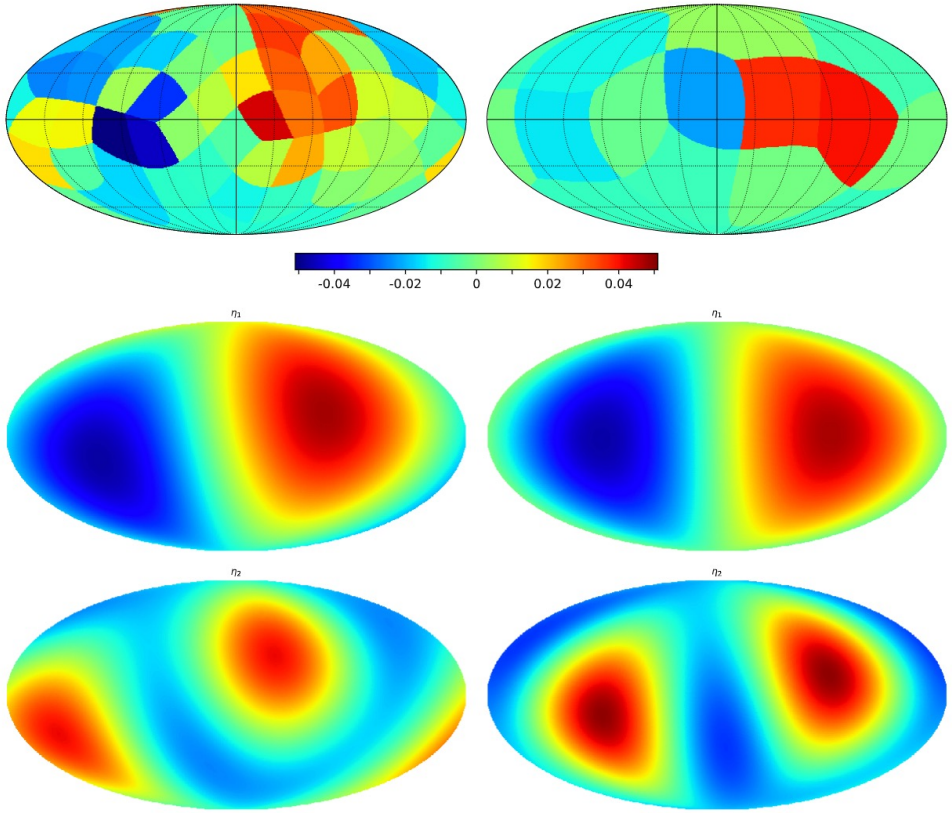

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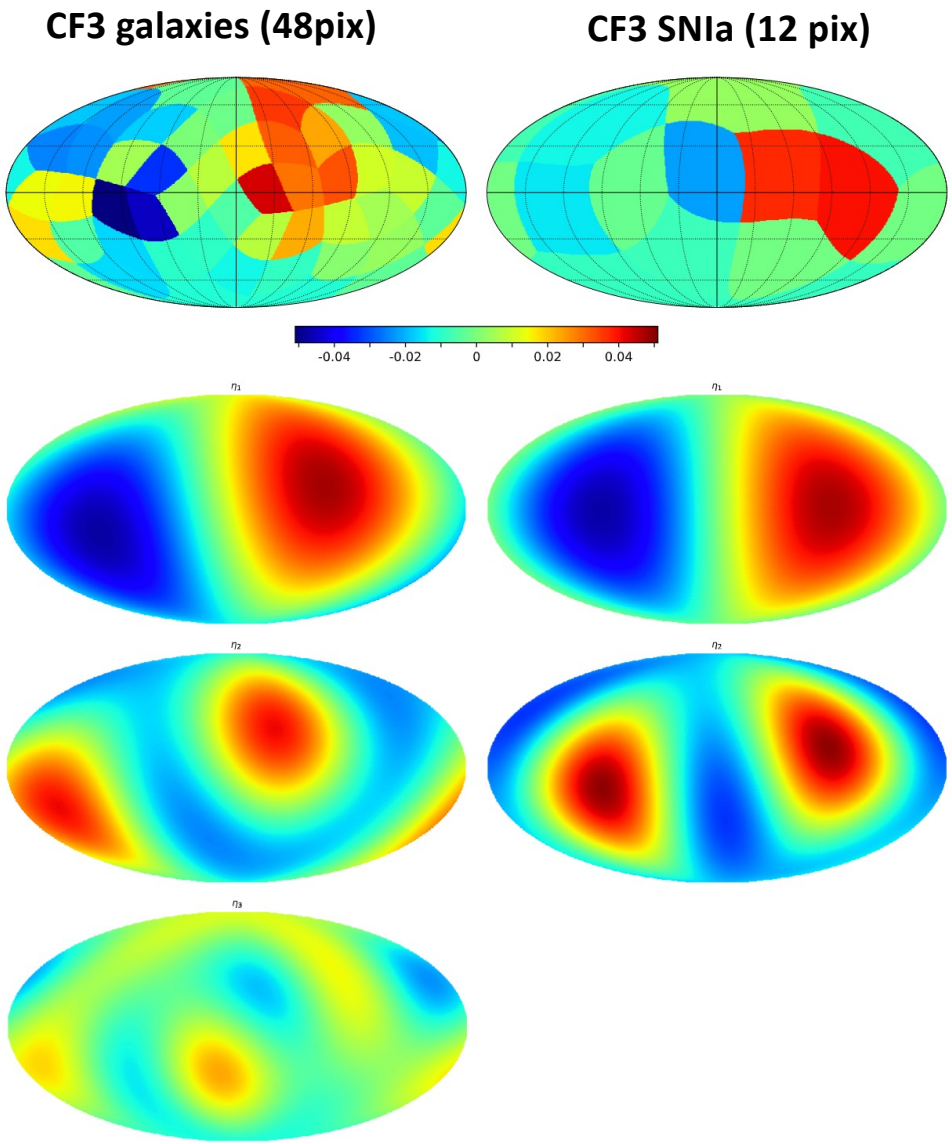
Quadrupole intensity is half that of the dipole

Alignement with the direction of the dipole

No quadrupole component in Pantheon data!



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Same intensity as quadrupole and hint of alignment

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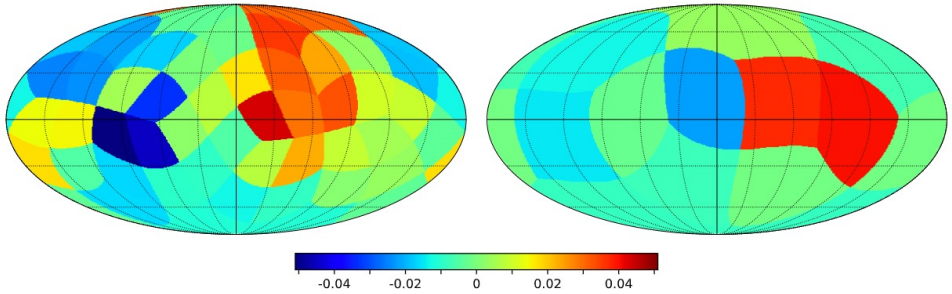

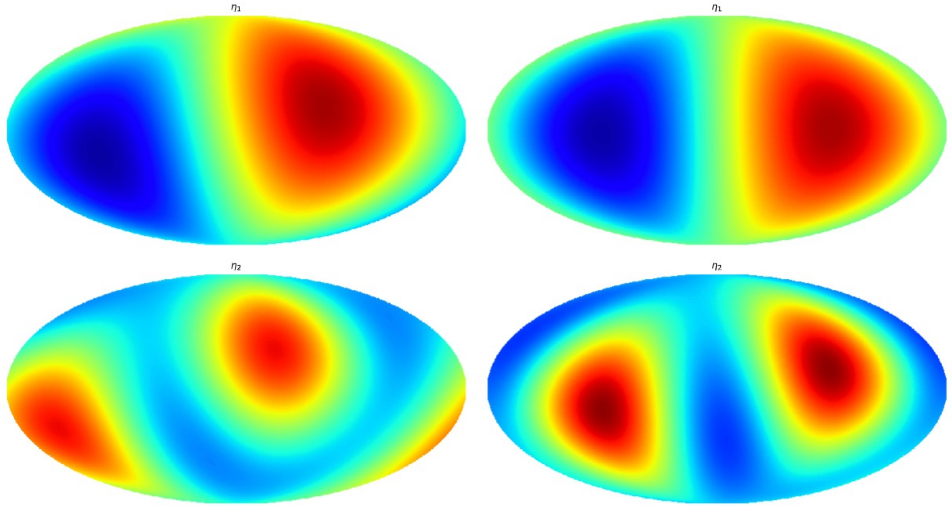

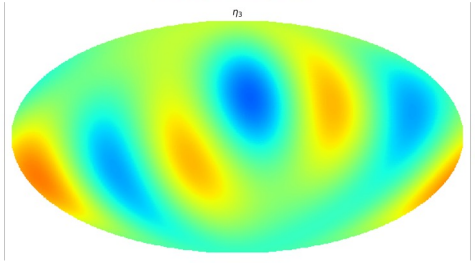

Octopole of full CF3 sample

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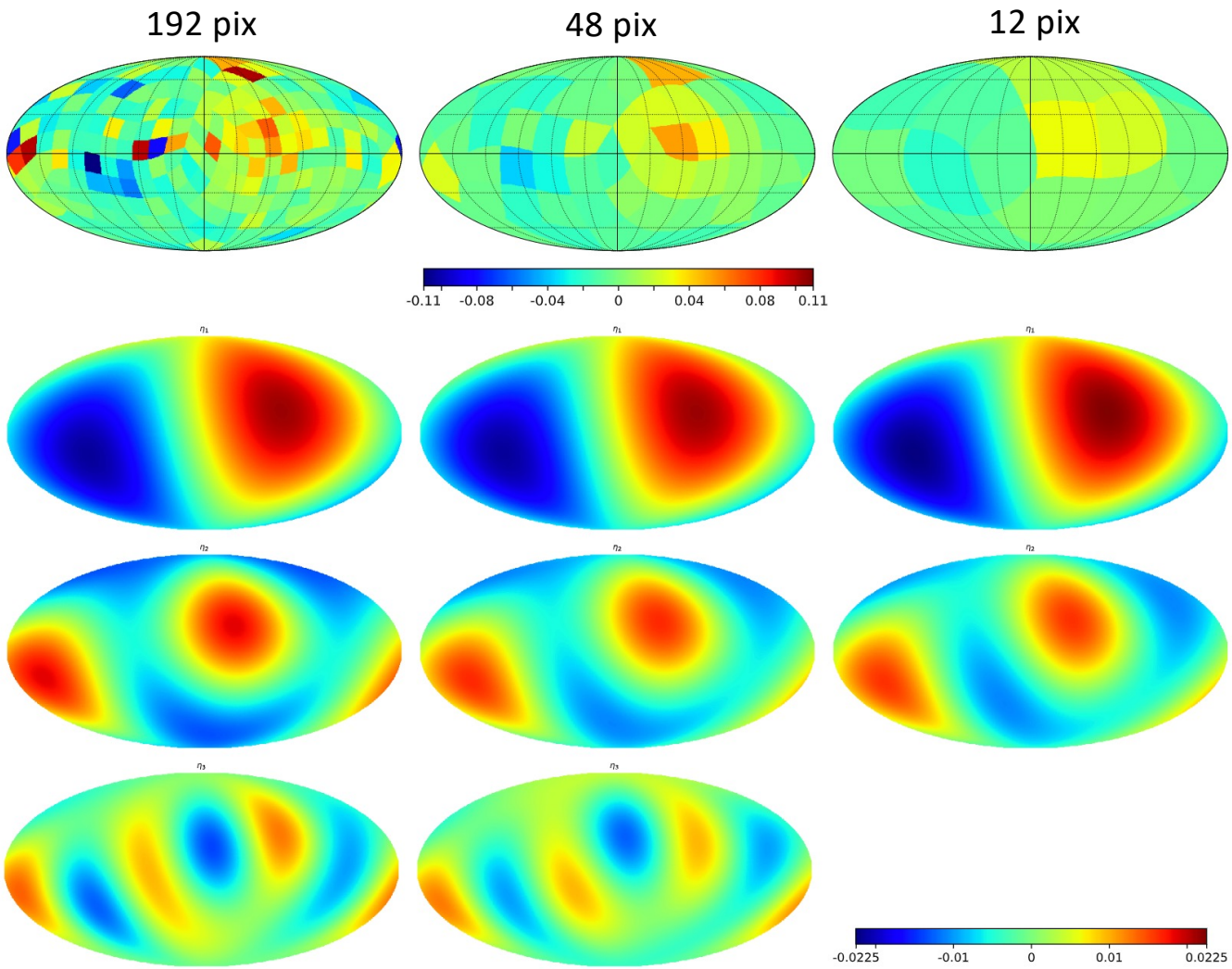
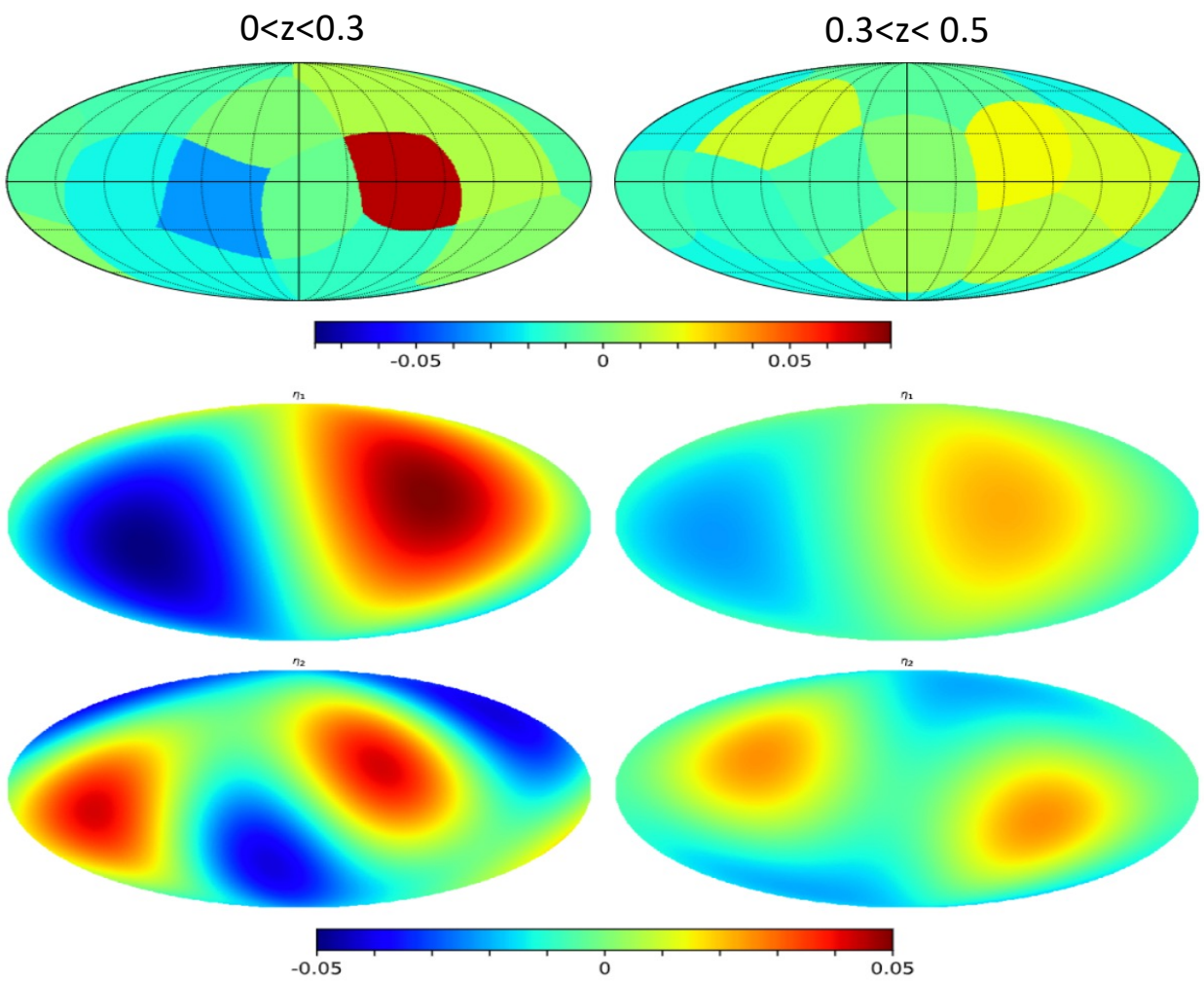
Errors and biases in estimating SH parameters

Independence from pixelisation strategy



Errors and biases in estimating SH parameters

Independence from the sample depth



Errors and biases in estimating SH parameters

1000 Monte Carlo simulations

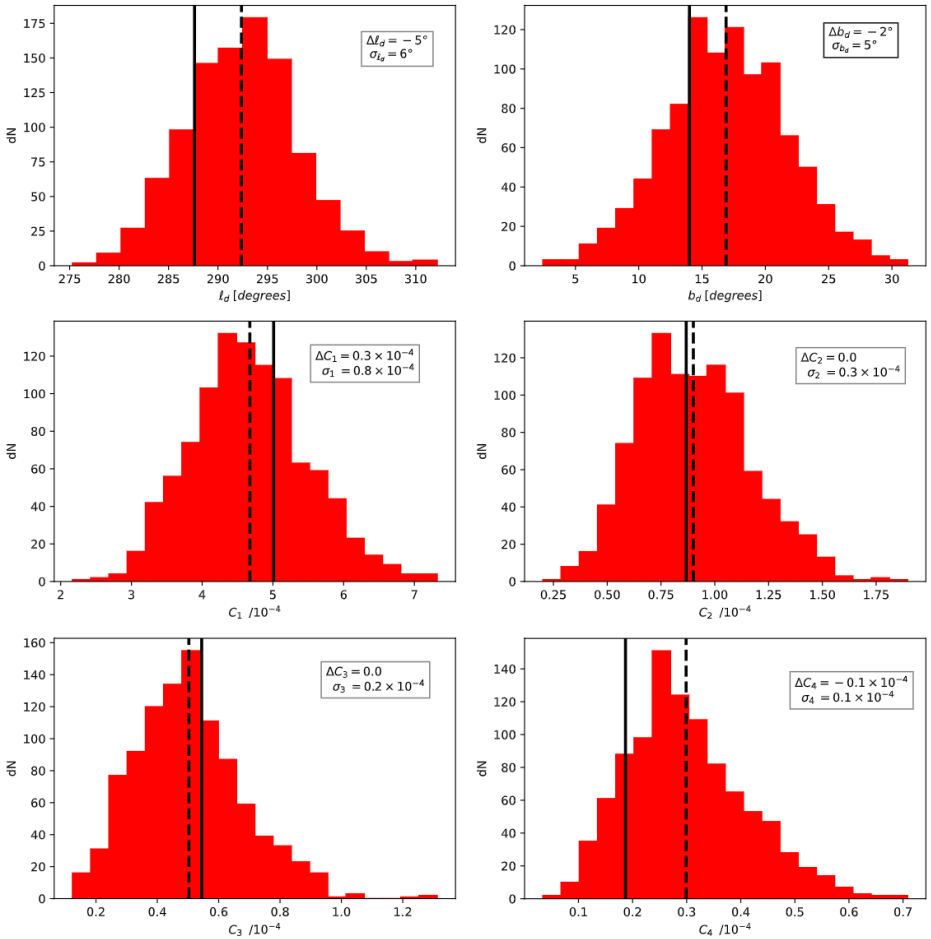
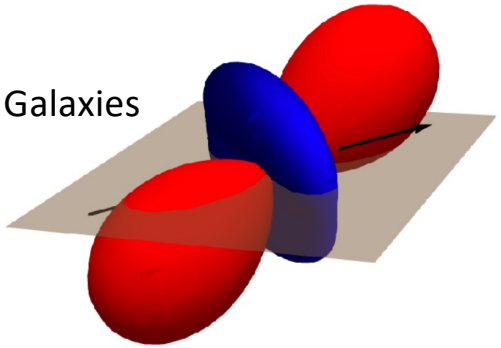


FIG. 25: Distribution of relevant SH parameters recovered from analysing, with the same pipeline used for real data, 1000 Monte Carlo simulations of the CF3 galaxy sample [0.01, 0.05] (48 pixels). The parameters of interest are the power spectrum coefficients C_l and the direction of the dipole (in galactic coordinates). The black line displays the simulated input value (fiducial model), while the dashed black line corresponds to the average of the distribution.

Axial symmetry

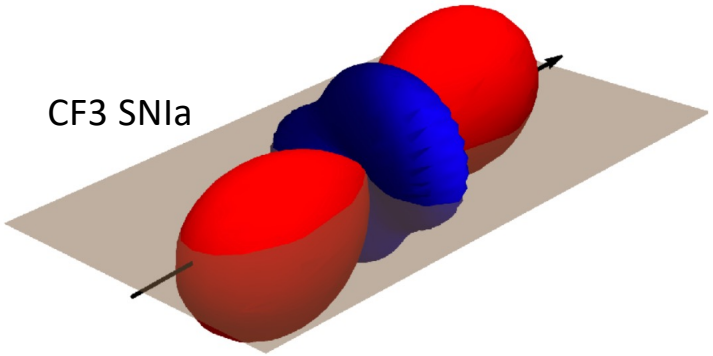
3D structure of the quadrupole

CF3 Galaxies



(Galactic plane shown for reference)

CF3 SNIa



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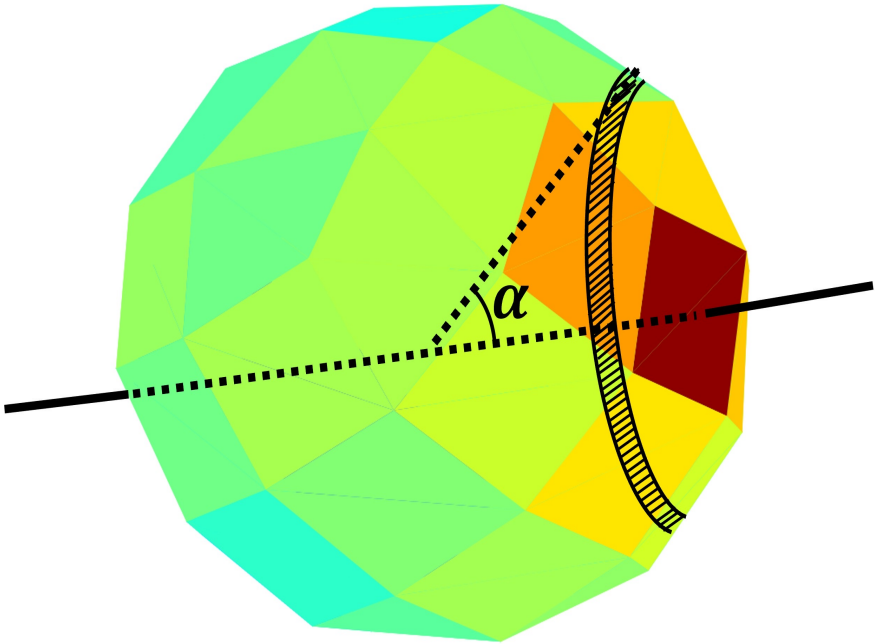
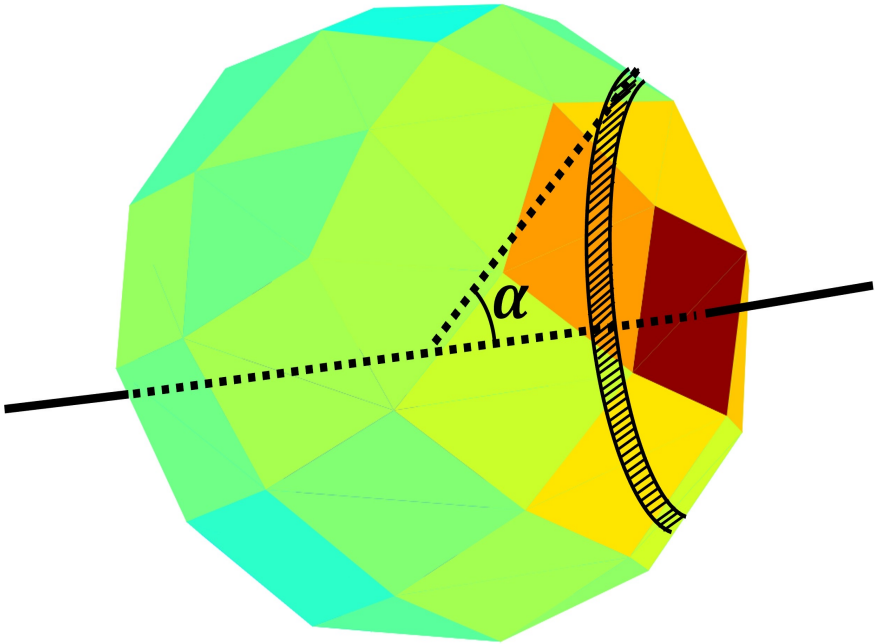


Sufficient to develop on the Legendre basis about the axis of symmetry

$\langle \eta \rangle = \sum a_l L_l$

Axial symmetry



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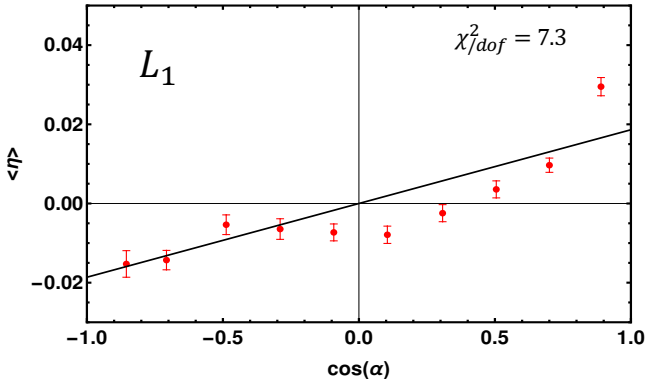

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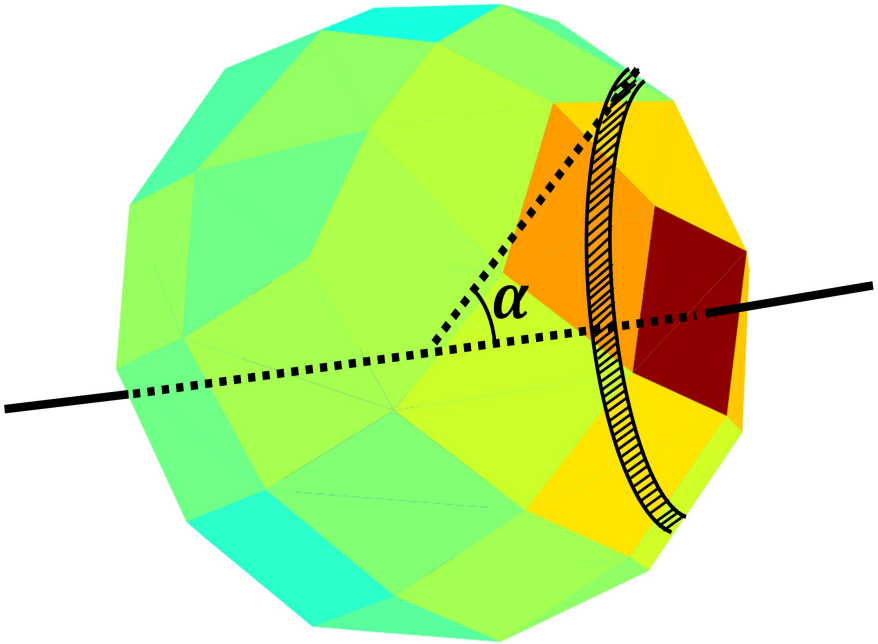

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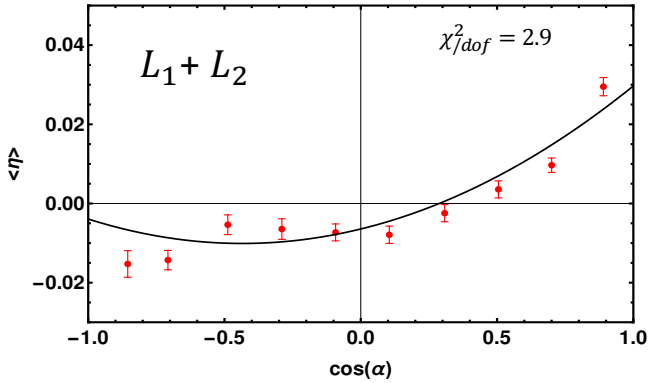

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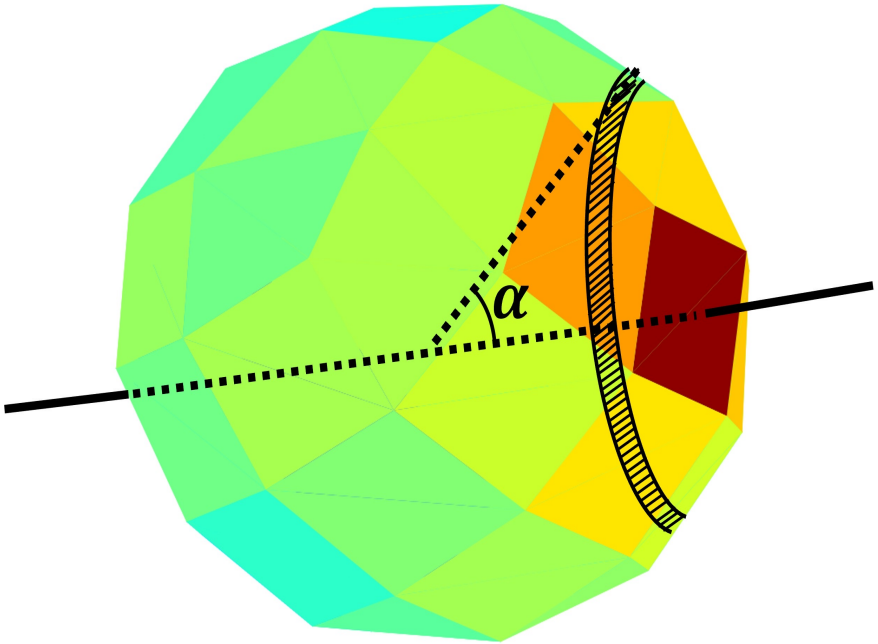

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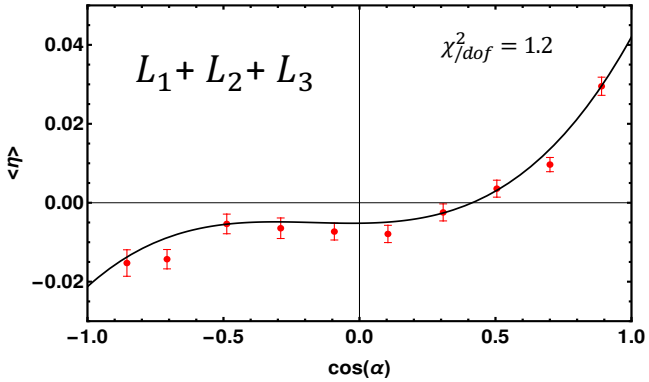

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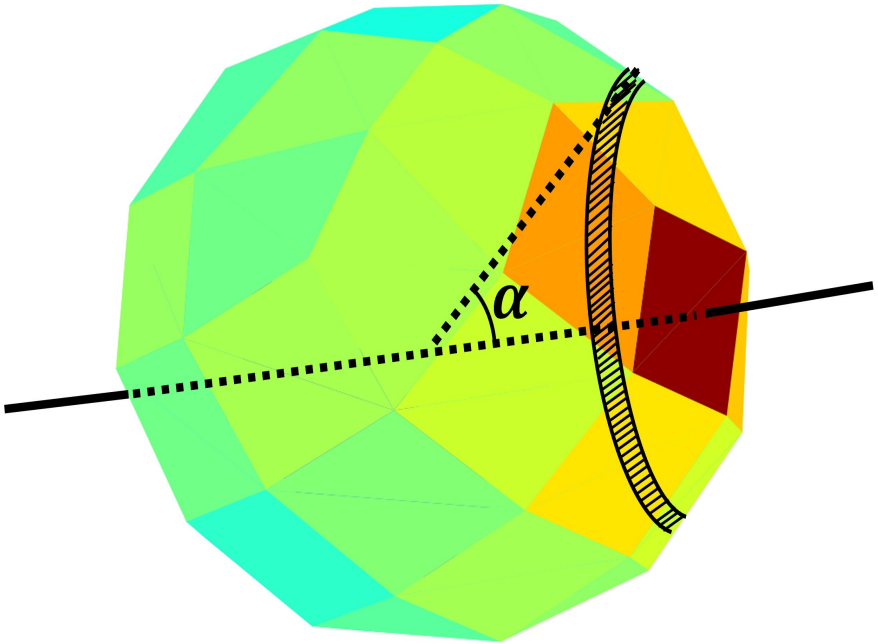

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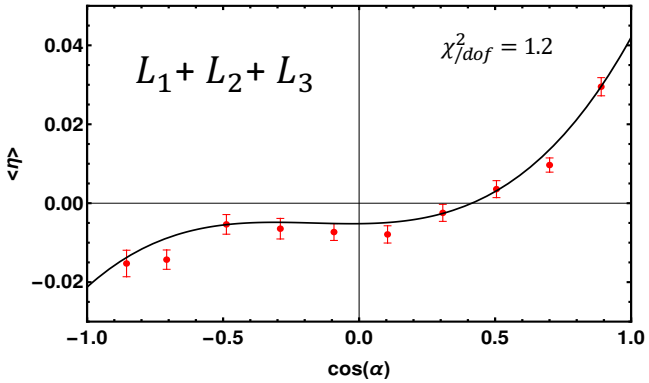
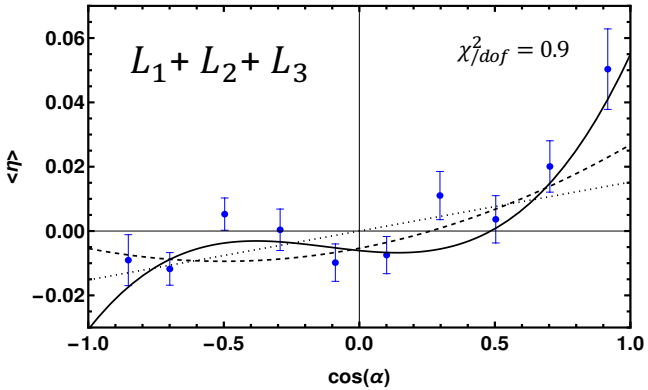
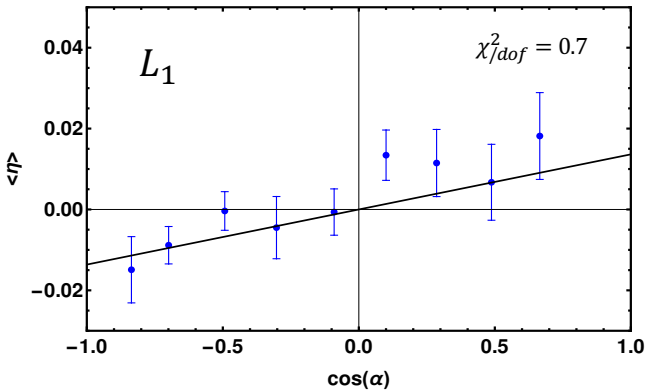


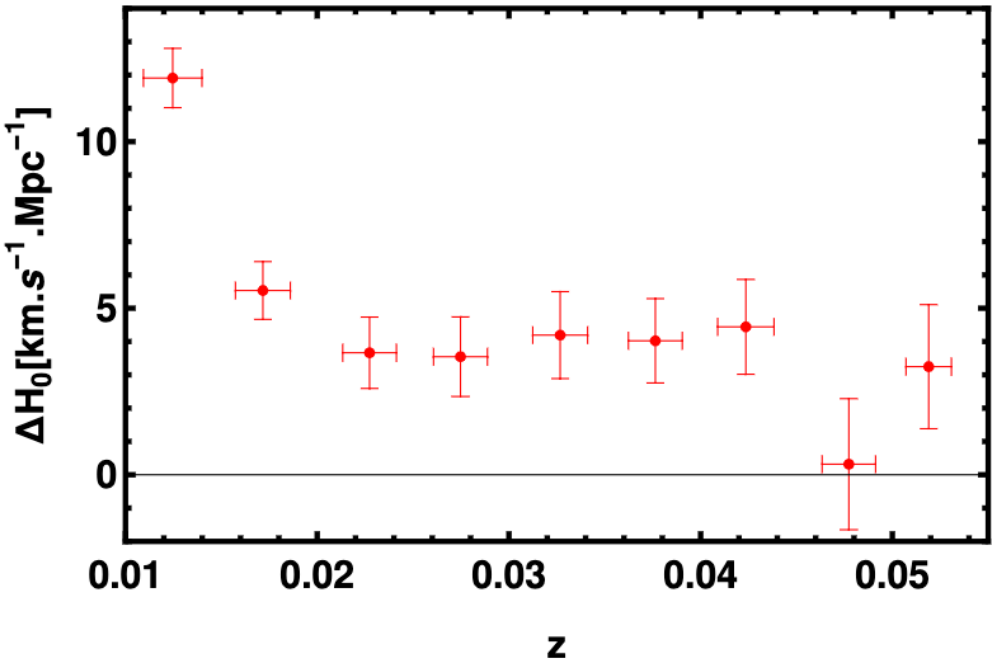
CF3 SNIa



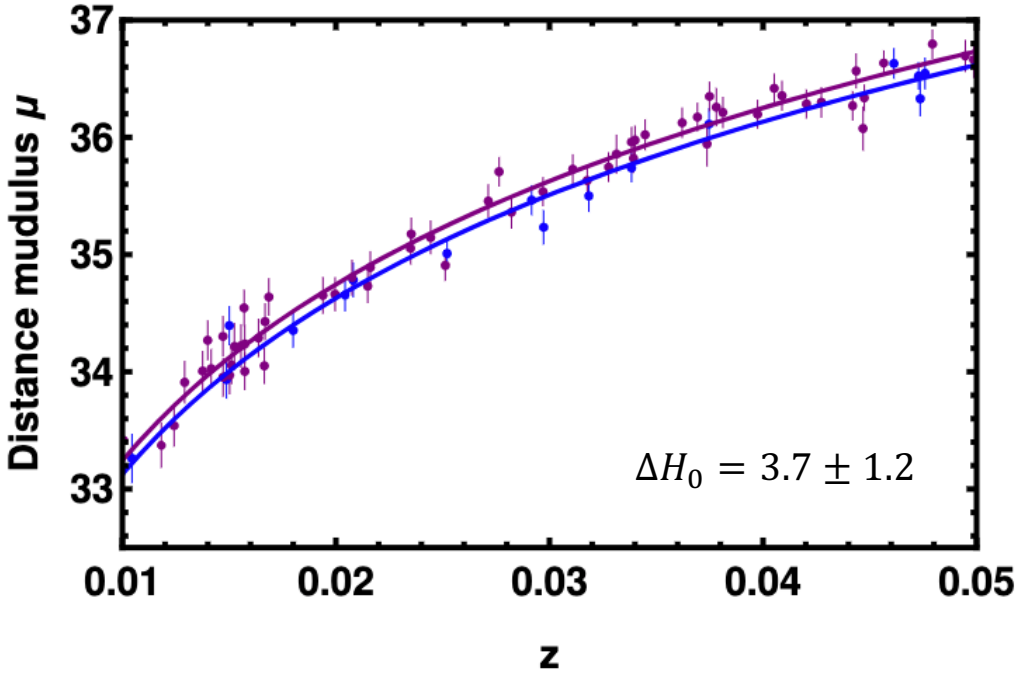
Pantheon



Implications for H_0

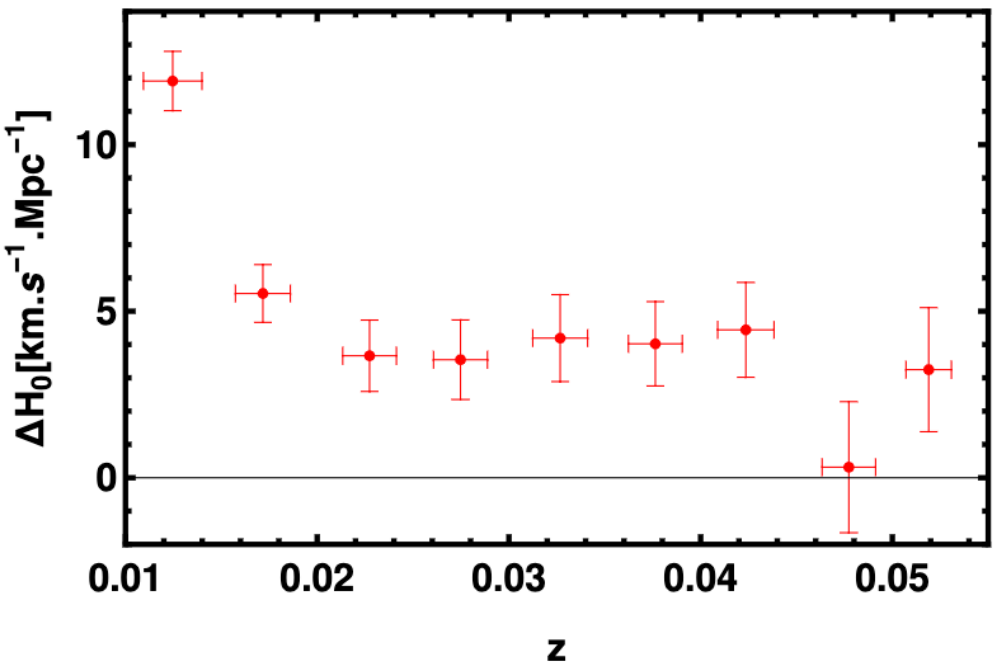


CF3 galaxy data: The difference between the best fitting H_0 in a solid angle of 60◦ in the apex direction and in the opposite direction.



Pantheon data: best fitting Hubble diagram in two solid angles in the apex direction (blue points) and in the anti-apex direction (purple points). No peculiar velocity corrections

Implications for H_0



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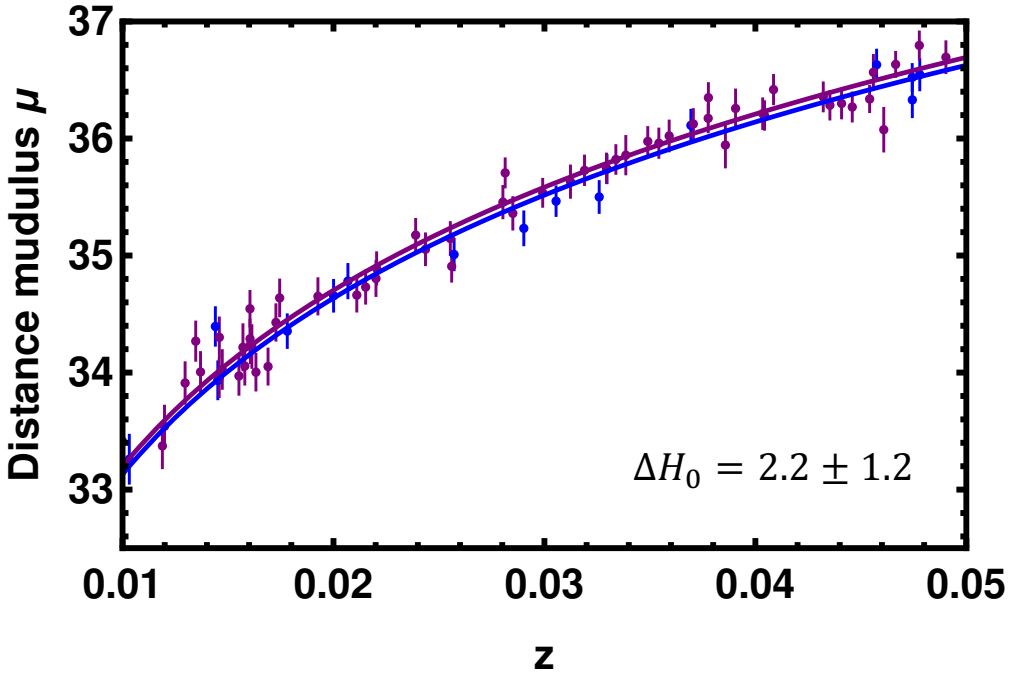

Pantheon data: best fitting Hubble diagram in two solid angles in the the apex direction (blue points) and in the anti-apex direction (purple points). peculiar velocity added!

Conclusions & Perspectives

Designed a new observable measuring the expansion rate fluctuations, and used it to determine the multipole structure of the linear redshift-distance relation in the local universe.

A simple dipole term is a poor representation of the angular fluctuations in the local expansion rate.
Find that the quadrupolar component for both galaxies and SNIa of the CF3 sample is

- substantial (half the amplitude of the dipole)
- aligned with the dipole (in the general direction of the bulk component of the LG velocity)
- axis-symmetric

Tentative evidence (from galaxy sample only) of the detection of an aligned octopole with an amplitude similar to that of the quadrupole.

Need to build on the current work by doing a more intensive data analysis with updated and enlarged datasets: CF4 (Kourkchi et al.), Pantheon+ (Scolnic's talk this morning)…

Interpret the salient features of the local expansion field in terms of alternative metrics that extend the predictive power of the FRW model to sub-uniform cosmic scales.

Progress on Old and New Themes in cosmology (PONT) 2023

2–5 May 2023
Palais des papes, Avignon
Europe/Paris timezone

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marco.cirelli@gmail.com

chris.marinoni@gmail.com

vivian.poulin@umontpell…

nicola.tamanini@l2it.in2…

The conference addresses the cardinal issues of the dark universe today, gathering a selected number of scientists working in cosmology and particle physics in the inspiring and monumental setting of Avignon. There will be both review talks by leading experts in each field and selected contributions, all aimed at encouraging in-depth debates. A certain amount of time will be devoted to discussion sessions.

Organizers: Philippe Brax *(CEA IPhT Saclay),* Francesca Calore *(LAPTh Annecy),* Marco Cirelli *(CNRS LPTHE Jussieu Paris),* Christian Marinoni *(CPT Marseille),* Vivian Poulin *(LUPM Montpellier)* , Nicola Tamanini *(L2IT Toulouse)*

Starts 2 May 2023, 08:35
Ends 5 May 2023, 20:00
Europe/Paris

Palais des papes, Avignon
Chambre du Trésorier
Go to map

There are no materials yet.

The conference will be organized along the following **broad categories**:

- Early universe
- Late universe
- Gravitational waves
- Astrophysical messengers of new physics